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Research Article

CLIMATE CHANGE AND AGROPASTORALIST SETTLEMENT IN THE SHASHE–LIMPOPO RIVER BASIN, SOUTHERN AFRICA: AD 880 TO 1700

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ABSTRACT

The expansion and decline of complex socio-political farming systems in the Shashe-Limpopo River Basin, southern Africa, has been linked to large-scale climate shifts in which increased rainfall favoured intensified agropastoral production and expanded settlement, while the onset of arid conditions led to collapse and abandonment of the area. This study uses stable nitrogen isotope ratios ($^{15}N/^{14}N$) from modern and archaeological fauna to construct a proxy-rainfall sequence for the region from AD 880 onwards. The resulting sequence provides a revised climatic context for agropastoral settlement of the river basin and evidence of greater climatic variation than previously documented. Stable nitrogen isotope data from the bone collagen of archaeological fauna show that settlement by Zhizo agropastoralists between AD 880 and 1010 took place under semi-arid conditions, with average annual rainfall of <500 mm. Results for sites dating between AD 1010 to 1290 are consistent with previous interpretations that the Leopard's Kopje A and B cultural period 'capitals' of K2 and Mapungubwe, respectively, rose to prominence under a trend towards increased average annual rainfall that was ≥500 mm. The data indicate also that the phase of increased moisture extended beyond the abandonment of Mapungubwe at AD 1290 and continued to be evident in fauna dating to the Moloko/Icon cultural period between AD 1310 and 1415. Data from the Moloko/Khami cultural period sites suggest that markedly drier conditions were not evident in the area until after AD 1450. Based on the isotope data, increased rainfall appears to have coincided with the expansion and intensification of settlement in the Shashe–Limpopo River Basin. Reconsideration, however, needs to be given to the correlation between the abandonment of Mapungubwe with the onset of arid conditions unfavourable for agropastoralism; other explanations, encompassing socio-economic and political choices, also must be sought.

Keywords: Iron Age, Shashe–Limpopo River Basin, South Africa, climate, farming, stable nitrogen isotopes.

INTRODUCTION

This study re-examines proposed correlations between climatic phases and the expansion and decline of complex socio-political systems and associated agropastoral economies in the Shashe–Limpopo River Basin, southern Africa (hereafter abbreviated to SLRB) (Fig. 1). Over the last decades, archaeological research has successfully reconstructed Zhizo and Leopard's Kopje A and B settlement sequences, which centred upon their respective capitals of Schroda, K2 and Mapungubwe, and their allied commoner sites. Researchers (e.g. Hanisch 1980; Eloff & Meyer 1981; Meyer 1998; Huffman 2000) have shown that these capitals coordinated the region in increasingly complex ways between AD 900 and 1290, culminating in a class-based society at Mapungubwe between AD 1220 and 1290 where political control was linked to an institution of sacred leadership. Site surveys by Huffman (2000) suggest that the SLRB experienced a dramatic population increase between AD 880 and 1290, estimated to rise from about 1900 to at least 9000 people (Huffman 2000: 23). This was followed by the rapid collapse of the Mapungubwe system shortly after AD 1290 (Meyer 1998), with population decrease and redistribution until after AD 1450, when large settlements were re-established in the river basin.

In the absence of specific palaeoclimatic and palaeoenvironmental data for the SLRB, the sequence of cultural change has been linked to the timing of large-scale climatic phases, primarily established for the northern hemisphere, and the subsequent affect on agropastoral production and trade (Huffman 1996; Meyer 1998; Plug 2000). According to this framework, the establishment of Zhizo communities, and the subsequent agropastoral intensification and political centralization through the Leopard's Kopje A and B sequences, overlapped with the warm and wet Medieval Warm Epoch from AD 900 to 1300. The abandonment of Mapungubwe coincided with the start of the cool and dry Little Ice Age from AD 1300 to 1850, when annual rainfall decreased, possibly to below the suggested 500 mm required for optimum dryland crop production (Doggett 1976; Purseglove 1976). The occurrence and timing of these climatic phases in southern Africa should be considered tentative, as correlations were made from a compilation of palaeoenvironmental data, but with low resolution dates, from different areas of the subcontinent (Tyson & Lindesay 1992).

Recently, however, greater clarity on the chronology and regional character of the AD 880 to 1800 climate has emerged from high-resolution stalagmite (Holmgren *et al.* 2001; Lee-Thorp *et al.* 2001; Tyson *et al.* 2002; Holmgren *et al.* 2003; Lee-Thorp 2004) and pollen (Scott *et al.* 2003) sequences obtained near Polokwane, located about two hundred kilometres to the southeast of the SLRB. These data suggest that between AD 880 and 1320 the climate of northeastern South Africa was generally slightly warmer and wetter than present, although still variable. The stalagmite sequence contains evidence of drier and possibly cooler events at ~AD 1000, 1200 and 1400, and starting at ~AD 1500 a subsequent climatic phase in which this region was cooler (~1°C), stormier, but generally drier than present, with the most severe conditions occurring

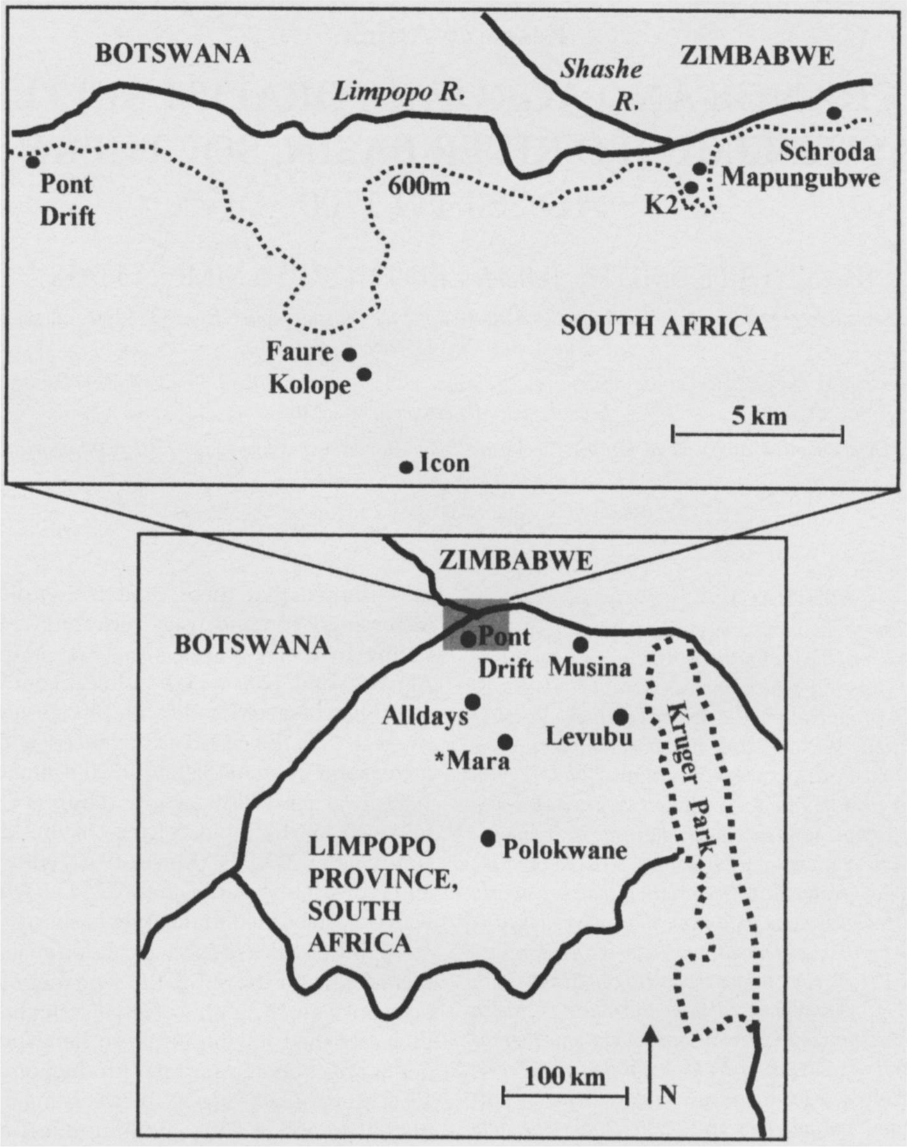

FIG. 1. *Location of the Shashe–Limpopo River Basin and the approximate location of sites and places mentioned in the text.*

sometime between AD 1700 and 1750. Drier conditions are also recorded for the pollen sequence, with a significant dry period at ~AD 1500. These findings place the extreme portion of the cool and dry phase much later than initially supposed. Tree-ring data from near Tzaneen, located 100 km northeast of Polokwane, support a post AD 1400 pattern of drier conditions (Norström *et al.* 2005) This study records dry periods in the early 1400s, mid-1500s and mid-1700, but also indicates that the late 1400s and 1600s were wetter.

One must, however, apply caution when extrapolating external climatic data to the SLRB, for local climate and environmental factors can differ. For example, the SLRB lies in the rain shadow of the Soutpansberg, situated ~100 km south and southeast. Presently, within the Soutpansberg the amount of annual rainfall is significantly higher than the SLRB, and increases from west to east. The effectiveness of this moisture is enhanced by an average annual temperature of 19.8°C, which is 2.2°C lower than the SLRB. A twenty-three-year climate record illustrates the rainfall variability between the two Soutpansberg weather stations at Mara and Levubu and those to the north at Alldays, Pont Drift and Musina (Fig. 2). Although rainfall fluctuations of the SLRB are often congruent with those to the south, the degree of these changes is not consistent across the region and areas are differentially impacted.

The climatic variability evident from the instrumental data emphasizes the need for a locally constructed climatic sequence for the SLRB that extends further back in time than instrumental records allow. To this end, we established a proxy rainfall baseline from comparative stable nitrogen isotope ($^{15}N/^{14}N$) analyses of modern herbivores sampled across a transect with different climatic zones. Although $^{15}N/^{14}N$ ratios in fauna are most frequently considered as trophic indicators, in herbivores these ratios are sensitive to aridity and through baseline studies we were able to correlate ratios to rainfall levels. We then measured $^{15}N/^{14}N$ ratios from herbivores excavated from agropastoralist sites in the SLRB, which span the period between AD 880 and 1700. From this study we aimed to quantify the rainfall conditions under which the SLRB was settled and major economic and political centres emerged and declined.

MATERIALS AND METHODS

NITROGEN ISOTOPE VARIABILITY IN THE ENVIRONMENT

Our study was based on previous research which demonstrated that increased aridity will cause the $^{15}N/^{14}N$ ratios in terrestrial soils, plants and animals to vary beyond the expected trophic level effect (for reviews see Ambrose 1993; Koch *et al.*

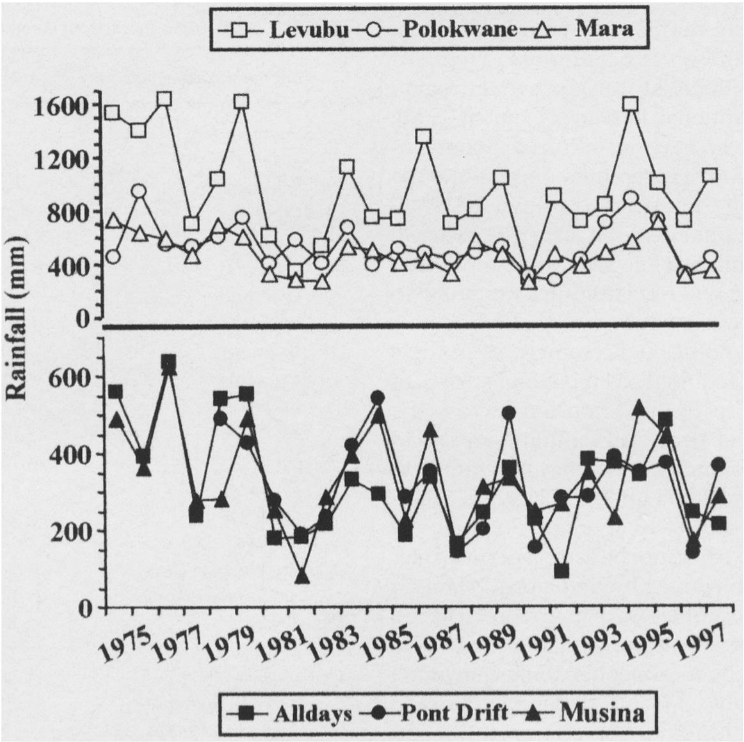

FIG. 2. *Annual rainfall variability for the Soutpansberg and areas to the north.*

1994). In a stable, non-water stressed environment, $^{15}N/^{14}N$ ratios move through trophic levels in a relatively predictable manner. At the primary level, plants obtain their nitrogen from the soils or the atmosphere. Reflecting the nitrogen composition of these sources, plants, in general, tend to have stable nitrogen isotope values in the range of ~0‰ to ~5.0‰ (Handley *et al.* 1999). Plant values may, however, be further influenced by soil types. For example, dense clay soils retain more of the heavier ^{15}N isotope relative to the lighter ^{14}N isotope, resulting in higher stable nitrogen values than porous sandy soils (Delwiche & Steyn 1970; Ledgard *et al.* 1984; Tieszen *et al.* 1984). Moving up a trophic level, the bone collagen value of an herbivore is elevated by ~3.0‰ to ~4.0‰, on average, relative to that of the plants consumed (Schoeninger *et al.* 1983; Sealy *et al.* 1987; Ambrose 1991; Kelly 2000).

In water-stressed environments with ≤400 mm of annual rainfall, such as present-day SLRB, the stable nitrogen isotope values of plants and herbivores are elevated compared to wetter regions (Virginia & Delwiche 1982; Heaton *et al.* 1986; Shearer & Kohl 1986; Sealy *et al.* 1987; Handley & Raven 1992; Thackeray *et al.* 1993; Handley *et al.* 1994). The elevated values are partly due to evaporation and erosion, leaving soils in drier regions with a higher amount of ^{15}N isotope, and partly due to plants and animals implementing mechanisms for coping with water stress. For instance, some tree species will develop deep root systems to take advantage of subsurface waters that tend to be enriched in the ^{15}N isotope. This occurs as shorter root plants take up the more mobile ^{14}N in soil nutrients leaving ^{15}N-enriched nutrients to filtrate down the soil profile (Letolle 1980; Mariotti *et al.* 1980; Boddey *et al.* 2000). Isotopic variation between these plants may be less pronounced where evaporation or erosion have removed a large percentage of ^{14}N isotopes from the near surface soil or where the lighter isotope is taken up by plants at quicker rate than can be replenished by organic decomposition (Shearer *et al.* 1983; Heaton 1987; Nadelhoffer & Fry 1994; Handley *et al.* 1994). The elevation in plant stable nitrogen values is reflected in those of herbivores, with a subsequent increase in values possibly caused by physiological processes in different herbivore species to conserve water and protein (Ambrose & DeNiro 1986; Sealy *et al.* 1987; Sponheimer *et al.* 2003).

MODERN SAMPLING ENVIRONMENT

The bones of modern free-range domesticated and wild herbivores and associated dietary vegetation from different climatic zones were analysed to determine whether their $^{15}N/^{14}N$ ratios varied significantly so as to discern past changes in rainfall levels for the SLRB. The samples were collected over a ~100 km transect that encompassed, from south to north, the geographical areas of Mara (Soutpansberg) to Pont Drift (SLRB) and eastwards to Musina (Fig. 1). Between 1999 and 2002, samples were donated or collected in the field with permission of land-owners and managers from farms and game reserves in the four main areas of Mara, Alldays, SLRB and Musina. The SLRB area was further sub-sampled between Pont Drift and the archaeological site of Schroda. From west to east the sub-areas included: Balerno, Riedel, Tuscanen, Den Staat, Venetia Game Reserve and Greefswald.

All areas sampled are semi-arid, but there is considerable variability in the amount of annual rainfall between the Soutpansberg and the areas to the north. Areas just south of the Soutpansberg record ≥500 mm of average annual rainfall, while those to the north receive ≤350 mm (South African Weather Service 1975–1998). In all four sampling areas, rainfall is predictably seasonal, beginning in October, peaking towards the end of January and into February, and tapering off in April. The intervening winter months of May to September are drier, each month receiving less than 10 mm of moisture. Low average annual rainfall and high variability are factors that diminish dryland agriculture production in the areas of Alldays, SLRB and Musina. A review of climate records (South African Weather Service) for these three areas indicate that from 1975 and 1998 annual rainfall ranged from ~140 mm to ~600 mm, with one extremely low year of 82.1 mm (see Fig. 2). Of particular note is that on only four occasions did the annual rainfall dip significantly below ~250 mm at the weather stations north of the Soutpansberg. This is the minimum amount of annual rainfall for reasonable, although not optimum, yields of sorghum and millet, the traditional African crops in the region (Leppan & Bosman 1923; National Research Council 1996). Two low rainfall years, however, have not occurred in consecutive years in areas within 50 km of each other. This follows the model for semi-arid regions in Africa (Lockwood 1988), whereby every year at least one area in a larger district will experience below average rainfall, while at the same time other areas within the same district will receive sufficient rainfall to support average crop yields and pasture growth.

To control for potential non-climatic sources of isotopic variation, sampling protocol required soil types and species of vegetation and herbivores to be held constant across the transect. Kalahari Sands cover nearly all sampling areas and there was no evidence of erosion in most of the areas sampled. An exception is the bank area of the Limpopo River, which has higher clay content and is subject to sporadic flooding. All sources of dietary vegetation could not be sampled, since over 120 species are potentially consumed by herbivores (Hanisch pers. comm.). Tree and grass samples were, therefore, selected from dominant vegetation types on the basis that they were observed by us, or reported by local people, to be consumed by the herbivore species analysed (Table 1). Sampled browse consisted of leaves from Acacia and Combretum trees, and graze was a mix of grass blades from a variety of species, including Aristida, Urochloa, Panicum and Digitaria. Where possible the same herbivore species or those with comparable dietary and digestive characteristics were selected from each sampling area to minimize other sources of variability in stable nitrogen isotope values.

ARCHAEOLOGICAL SAMPLES

We sampled *Bos taurus* and ovicaprid from the archaeological sites of Schroda, Pont Drift, K2, Mapungubwe, Icon, Faure and Kolope. All sites are in close proximity to each other (see Fig. 1), and while no one site spans the entire period between AD 880 and 1700, together, they provide a stratigraphic sequence that chronologically encompasses most of the early and later agropastoralist settlement history of the SLRB. To limit the possibility of multiple sampling of one individual, bone samples were taken from individually distinct adult mandibles, maxilla and molar roots.

MATERIAL PREPARATION AND ANALYSIS

The δ^{15}N values of modern and archaeological fauna were obtained from bone collagen extracted according to the procedure outlined by Sealy *et al.* (1987) and Lee-Thorp *et al.* (1989). Following common practice, 'collagen' refers to the acid-insoluble protein component of the skeletal organic phase. The measured isotopic value from a collagen sample reflects, roughly, the life average of an individual. In preparation for collagen extraction the bone was: 1) brushed clean of surface dirt; 2) broken into small chunks, ~10 mm in size, and 3) sonicated in distilled water to remove extraneous subsurface material. Lipids were removed from modern bone through an overnight soak in a methanol:choroform:water (2:1:0.8 v/v) solution. Acid insoluble collagen was isolated by acid hydrolysis in 0.2 M hydrochloric acid (HCl) solution until gas bubbles stopped evolving and the sample was a flexible, translucent replicate of the original bone. This process took a few days to two weeks to complete depending on the density of the bone, during which time the mixture was agitated and the HCl solution replaced every ~3 days. The resulting collagen sample was rinsed to neutrality with distilled water, and then soaked for 24 hours in 0.125 M sodium hydroxide (NaOH) solution to remove humates. Following a final rinse to neutrality, the sample was freeze-dried.

TABLE 1: *δ^{15}N values for modern domesticated and wild herbivores.*

Species according to area	δ^{15}N (‰)	Diet
Soutpansberg (Mara)		
Equus sp.	7.3	Grazer
Equus sp.	6.7	Grazer
Ovicaprid	10.6	Mixed-feeder
Ovicaprid	9.3	Mixed-feeder
Ovicaprid	8.9	Mixed-feeder
Ovicaprid	6.6	Mixed-feeder
Bos taurus	9.7	Grazer
Bos taurus	9.6	Grazer
Bos taurus	8.7	Grazer
Bos taurus	7.9	Grazer
Bos taurus	7.7	Grazer
Bos taurus	7.6	Grazer
Bos taurus	6.9	Grazer
Bos taurus	6.1	Grazer
Alldays		
Aepyceros melampus	11.5	Mixed-feeder
Alcelaphus buselaphus	10.7	Grazer
Oryx gazella	10.0	Grazer
SLRB (Venetia)		
Aepyceros melampus	11.5	Mixed-feeder
Aepyceros melampus	10.8	Mixed-feeder
Aepyceros melampus	10.6	Mixed-feeder
Aepyceros melampus	10.5	Mixed-feeder
Aepyceros melampus	10.4	Mixed-feeder
Aepyceros melampus	9.7	Mixed-feeder
Aepyceros melampus	9.0	Mixed-feeder
Connochaetes taurinus	12.5	Grazer
Connochaetes taurinus	11.4	Grazer
Connochaetes taurinus	10.4	Grazer
Connochaetes taurinus	10.4	Grazer
Connochaetes taurinus	10.2	Grazer
(Balerno)		
Bos taurus	10.3	Grazer
(Riedel)		
Aepyceros melampus	12.3	Mixed-feeder
Aepyceros melampus	11.9	Mixed-feeder
Aepyceros melampus	10.5	Mixed-feeder
Aepyceros melampus	9.5	Mixed-feeder
Aepyceros melampus	9.4	Mixed-feeder
Aepyceros melampus	9.1	Mixed-feeder
(Tuscanen)		
Connochaetes taurinus	14.3	Grazer
(Den Staat)		
Loxodonta africana	10.8	Mixed-feeder
Equus quagga	11.4	Grazer
Equus quagga	11.1	Grazer
Equus quagga	9.8	Grazer
Connochaetes taurinus	14.5	Grazer
Musina		
Giraffe camelopardalis	10.8	Browser
Tragelaphus strepsiceros	9.4	Browser
Sylvicapra grimmia	9.8	Browser

Approximately 0.6 mg of bone collagen and 2.5 mg of clean plant material were required for mass spectrometry. The weighed sample was secured in a foil cup that was dropped from a sample carousel into a carbon/nitrogen elemental analyser where it was combusted to release CO_2 and N_2 gases, which flowed into the mass spectrometer for analysis. The nitrogen composition of the sample was determined by measuring its isotope ratio of $^{15}N/^{14}N$ relative to that of the

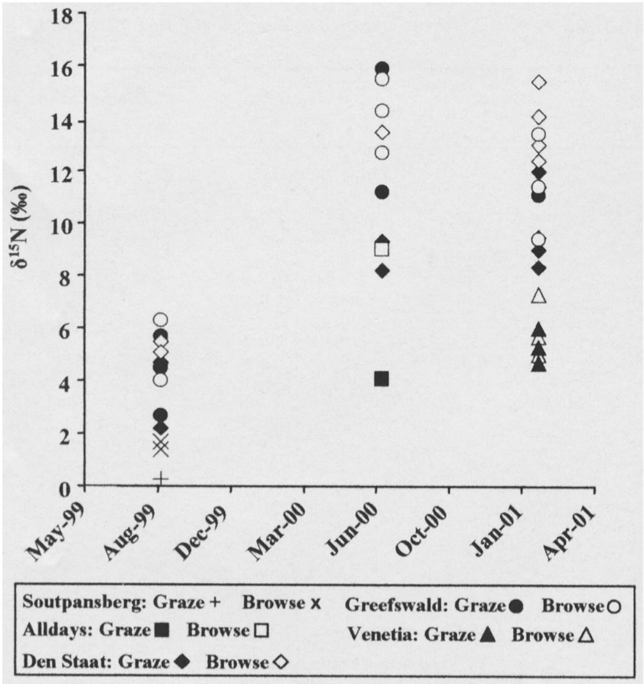

FIG. 3. *Plotted δ^{15}N values for modern vegetation.*

standard AIR, with the resulting value expressed as δ^{15}N in parts per mil (‰) as determined by the formula: δ^{15}N (‰) = ($^{15}N/^{14}N_{sample}/\,^{15}N/^{14}N_{standard}-1$) × 1000. The raw sample value was corrected using a three point regression calculated from the international and laboratory standards that were interspersed in the sample carousel. Repeat measurements of the standards indicate that a precision of ±0.2‰ was obtained for δ^{15}N determinations.

RESULTS

MODERN VEGETATION

The wide range of δ^{15}N values for grass, 0.3‰ to 12.0‰, and browse, 1.4.‰ to 15.4‰ underscores the climatic variability that prevails in this semi-arid region. When plotted (Fig. 3), the δ^{15}N values for both graze and browse separate out according to rainfall levels and their collection period. The Soutpansberg values of 0.3‰ for graze and 1.4‰ and 2.0‰ for browse are reflective of the average annual rainfall of >400 mm for this area. This contrasts to the obvious increase in plant values from the more arid areas to the north, in which average values for graze and browse are 7.5 ± 3.6‰ (*n* = 19) and 10.2 ± 4.0‰ (*n* = 20), respectively.

It should be noted that the exceptionally high values for plants collected from the floodplains of Den Staat and Greefswald in June/July 2000 and February 2001 exceed those expected for arid environments, and do not correspond with values for plants sampled at the same time from the other SLRB sub-areas and Alldays. These higher values are most likely due to the residual effect of floodwaters depositing ^{15}N-enriched clay sediments and removing the lighter ^{14}N-enriched sediments (Shearer *et al.* 1983; Heaton 1987; Gartner 1993; Nadelhoffer & Fry 1994) as the water inundated the lower sections of Den Staat and Greefswald in the summer months of 2000. Further ^{15}N-enrichment with soil depth could account for deeply rooted trees having even higher δ^{15}N values compared to grasses. Excluding plants that were potentially impacted by the flood conditions, more typical average values for plants from Alldays and the SLRB sub-areas would be 4.4 ± 1.4 (*n* = 9) for graze and 5.9 ± 1.6‰ (*n* = 8) for browse.

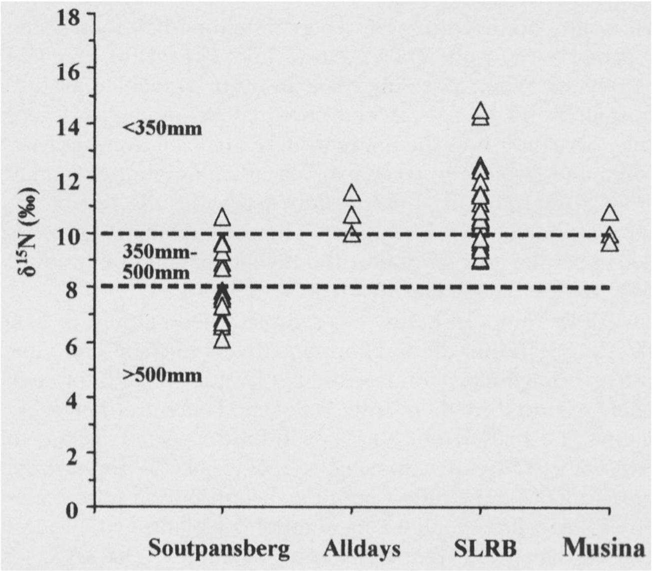

FIG. 4. *Plotted δ^{15}N values for modern herbivores and correlated average annual rainfall.*

MODERN HERBIVORES

Bone collagen δ^{15}N values from the domesticated and wild herbivores are given in Table 1, and plotted in Fig. 4 according to collection areas. From the graph, a bimodal distribution is evident that corresponds to a south to north decrease in average annual rainfall. For the Soutpansberg area of Mara, where average annual rainfall is ~500 mm, the average δ^{15}N value is 8.1 ± 1.4‰ (*n* = 14). Information on the approximate life span of the individual *Bos taurus* and ovicaprid allows values to be further separated into drier and wetter years. Regardless of species, animals born between 1990 and 1994 have higher δ^{15}N values of 8.7‰ to 10.6‰ (*n* = 6), compared to those born between 1995 and 1998, which have lower values of 6.1‰ to 7.9‰ (*n* = 8). The elevated values coincide with drier years between 1990 and 1994, in which the average annual rainfall was 465 mm (Table 2). In the following set of years, 1995 to 1998, the average annual rainfall increased to 536 mm. It is not known exactly when individual animals died prior to the 1999 collection date, but it was not more than two years (Mara Agricultural Research Station, pers. comm.).

The δ^{15}N values for herbivores from Alldays, SLRB and Musina range from 9.0‰ to 14.5‰, with an average value of 10.8 ± 1.4‰ (*n* = 30). These δ^{15}N values, along with the drier 1990 to 1994 Mara values, accord well with the model of δ^{15}N values increasing with decreasing rainfall. Table 2 shows that from 1990 to 1994 average annual rainfall did not exceed 300 mm for weather stations located at Alldays, Pont Drift and Musina, and from 1995 to 1998 it was not above 400 mm. During the 1990 to 1994 dry period, however, there was annual variability between the three areas (see Fig. 2). In 1990, for instance, Pont Drift recorded ~500 mm of rainfall, even though Pont Drift and Alldays received only ~350 mm. Further

TABLE 2. *Average annual rainfall for sampling areas between 1990 and 1998 (data from the South African Weather Service).*

Weather stations	Average annual rainfall (mm)	
	1990 to 1994	1995 to 1998
Mara	465	536
Alldays	*241*	*397*
Pont Drift	*283*	*363*
Musina	*297*	*362*

variability occurred in 1995 when annual rainfall for Musina reached ~600 mm while Alldays and Pont Drift received <500 mm. When assessing the amount of available moisture for plants and animals, these values may be somewhat deceptive. Areas north of the Soutpansberg are 2.2°C warmer than Mara and frequently receive a substantial amount of rainfall from a few monthly thunderstorms, leaving the rest of the month without rain. Thus, even when annual rainfall exceeds 400 mm, uneven distribution and higher evaporation produce δ^{15}N values that are elevated relative to Mara.

All the modern herbivores sampled died before the 2000 flooding of the Shashe and Limpopo Rivers, and consequently, the associated elevation in plant δ^{15}N values would not have been recorded in their bone collagen. Therefore, herbivore values of ≥10.0‰, which are beyond the expected average of 8.0‰ to 9.0‰ (plant value plus ~3.0‰ to ~4.0‰ trophic level enrichment), must reflect additional contribution from water stress, or a life average consumption of plants with values higher than those recorded from our survey. The effect of flooding on vegetation δ^{15}N values remains a consideration in relation to the SLRB archaeological sequence. If, as was the case prior to the historical construction of dams and weirs, the Shashe and Limpopo Rivers flooded regularly in the past (Wellington 1955), the δ^{15}N values for floodplain vegetation may have been frequently elevated by 5‰ to 10‰ compared to the vegetation of the surrounding areas. Herbivores feeding on active floodplains could potentially give a false 'extreme arid' signature. The archaeological herbivores, however, show no elevated values consistent with feeding on flood-affected vegetation. Animals from the AD 880 to 1700 sequence have δ^{15}N values ranging between ~5.0‰ to ~13.0‰, with the vast majority of values not exceeding 10.0‰. This is a range that is similar to the modern comparative samples from the Mara, Alldays, SLRB sub-areas and Musina.

ARCHAEOLOGICAL RESULTS

Discussion of the δ^{15}N values for archaeological *Bos taurus* and ovicaprid bone collagen is carried out according to the referenced sites, the calibrated radiocarbon dates and the five cultural periods outlined in Table 3. Doing so facilitates comparison with existing interpretations that link possible regional climatic events to the SLRB cultural sequence. This allows also for the recognition of localized climatic conditions, within large-scale trends, that may have coincided with periods of agropastoral production, population intensification and changing political and social structures.

The stable nitrogen isotope data and resulting climatic interpretation are presented at two scales. First is at a relatively short-term scale, which is represented by an intra-cultural period comparison of individual and average δ^{15}N values from layers within each site. Second is at a long-term scale, spanning AD 880 to 1700, obtained from comparison of the inter-site and inter-cultural period δ^{15}N averages (Fig. 5). Pre-colonial rainfall levels are estimated by comparing the archaeological isotope readings with the modern indices established above. The overall sequence is then set within a larger regional climatic context for AD 880 onwards.

1) AD 880 to 1010 (Zhizo Period)

The average δ^{15}N values of *Bos taurus* and ovicaprids from the Zhizo sequence at Schroda (*Bos taurus*: 9.2±1.1‰, n = 18 and ovicaprids: 9.1±1.7‰, n = 57) and Pont Drift (*Bos taurus*: 8.5±0.8‰, n = 9 and ovicaprids: 8.7±1.0‰, n = 32) are comparable to modern herbivore values associated with an average annual rainfall of 350 mm to 450 mm. The average δ^{15}N values,

TABLE 3. *Average δ^{15}N values for archaeological Bos taurus and ovicaprid per site layers.*

Site layers	*Bos taurus* δ^{15}N (‰)	Ovicaprid δ^{15}N (‰)	Calibrated AD dates
		Zhizo: Schroda[A]	
6	9.0 ± 1.7; n = 3	9.6 ± 1.2; n = 6	910–1010 (Pta-1819)
7	10.3 ± 0.2; n = 3	9.0 ± 2.1; n = 9	890–1000 (Pta-7664)
8	8.5 ± 2.7; n = 4	10.1 ± 1.4; n = 10	890–965 (Pta-7666)
9	9.8 ± 1.0; n = 3	8.8 ± 1.0; n = 8	880–990 (Pta-1967)
10	8.5 ± 1.8; n = 4	8.6 ± 1.3; n = 17	
11		10.0 ± 1.7; n = 4	
12	8.6; n = 1	9.3 ± 1.2; n = 3	
Site Avg.	**9.2 ± 1.1; n = 18**	**9.1 ± 1.7; n = 57**	
		Zhizo: Pont Drift[A,B]	
5		8.2 ± 1.4; n = 3	910–1010 (Pta-1961)
6		8.4 ± 1.0; n = 4	890–1010 (Pta-1959)
7		8.7; n = 1	
8		9.8; n = 1	
9	8.2; n = 1	8.8 ± 0.3; n = 5	
10		9.4 ± 1.3; n = 5	
11	8.7 ± 1.2; n = 3	8.5; n = 2	
12		8.6 ± 0.4; n = 5	
13	9.0; n = 1	9.2 ± 0.4; n = 2	
14	8.3 ± 0.7; n = 4	8.0 ± 1.6; n = 4	
Site Avg.	**8.5 ± 0.8; n = 9**	**8.7 ± 1.0; n = 32**	
		Leopard's Kopje A: Schroda[A,B]	
2	9.0 ± 0.0; n = 2	8.7; n = 1	1010–1040 (Pta-7659)
3		9.2 ± 1.8; n = 3	
4	6.1; n = 1	8.6 ± 0.8; n = 2	
5	8.3 ± 0.3; n = 2	9.3 ± 1.0; n = 6	
Site Avg.	**8.1 ± 1.2; n = 5**	**9.1 ± 1.1; n = 12**	
		Leopard's Kopje A: K2[C]	
1	7.0 ± 0.3; n = 2	8.1 ± 0.7; n = 3	1140–1220 (Pta-6073)
2	7.3 ± 1.4; n = 7		1050–1100 (Pta-6073)
3	7.8; n = 1		1030–1170 (Pta-2051)
6	8.4 ± 2.2; n = 4		
7	7.5 ± 1.6; n = 2	8.1 ± 0.5; n = 3	
8	7.3; n = 1	7.4 ± 1.7; n = 5	
9		6.5 ± 1.5; n = 6	
Site Avg.	**7.5 ± 1.4; n = 17**	**7.3 ± 1.4; n = 17**	
		Leopard's Kopje A: Pont Drift[A]	
1		10.8 ± 1.3; n = 5	1200–1270 (Pta-1818)
3	7.6 ± 2.4; n = 3	7.7 ± 0.8; n = 2	
4		9.7 ± 0.6; n = 5	
Site Avg.	**7.6 ± 2.2; n = 3**	**9.8 ± 1.4; n = 12**	
		Leopard's Kopje B: *MST[C]	
2		7.5 ± 0.3; n = 2	1260–1290 (Pta-1209)
3		7.3 ± 4.0; n = 2	1190–1260 (Pta-1156)
4		5.9; n = 1	1190–1260 (Pta-0768)
5		9.1 ± 1.8; n = 2	
6		8.8 ± 3.0; n = 2	
9	7.9; n = 1	9.5 ± 2.6; n = 3	
10	6.8 ± 1.2; n = 2		
11	8.6; n = 1		
13	7.8; n = 1	7.5 ± 0.5; n = 3	
Site Avg.	**7.9 ± 0.1; n = 2**	**7.9 ± 1.2; n = 18**	
		Leopard's Kopje B: +MK1[C]	
4	7.4; n = 1	7.8 ± 1.0; n = 2	1190–1270 (Pta-1158)
5	5.8; n = 1	6.3 ± 0.1; n = 3	1210–1270 (Pta-1159)
7	9.6 ± 0.2; n = 2	8.4 ± 0.5; n = 3	
8	8.1 ± 0.4; n = 3	7.5; n = 1	
9	13.2; n = 1	8.5 ± 0.9; n = 3	
10	7.3 ± 0.3; n = 2	8.5 ± 1.2; n = 7	
11	6.3; n = 1	8.7 ± 0.8; n = 9	
Site Avg.	**8.2 ± 2.5; n = 11**	**7.9 ± 0.9; n = 28**	
		Moloko/Icon: Icon[B,D]	
1		**7.1 ± 1.5; n = 9**	1310–1415 (Pta-1652)
		Moloko/Khami: Faure[E]	
1	**8.2 ± 0.8; n = 5**	**8.4 ± 1.4; n = 10**	1660–1685 (Pta-7970) 1475–1640 (Pta-7971)
		Moloko/Khami: Kolope[E]	
1		**8.9 ± 1.8; n = 5**	1520–1655 (Pta-7970)

References for sites sampled and AD dates: [A]Hanisch 1980; [B]Hanish 1981; [C]Meyer 1998; [D]Hanish 1979; [E]G. Lathey and T. Huffman, pers. comm.

*Mapungubwe Southern Terrace – commoner occupation.

+Mapungubwe Hill Top – elite occupation.

however, mask some individual variability. For instance, eleven of the animals from Schroda and five from Pont Drift have values of <8.0‰. These lower values are from samples sporadically distributed throughout the depositional sequence of both sites, and suggest episodes in which annual rainfall reached ≥500 mm. On the other hand, 24 animals from Schroda and three from Pont Drift have values of between 10.0‰ and 12.0‰, which correlate to a present-day average annual rainfall of ≤350 mm. Each layer from Schroda has at least one value of >10.0‰. In general, the Zhizo isotope values and inferred rainfall pattern are similar to those for the present-day SLRB; predominately semi-arid with variable periods of increased and decreased rainfall.

2) AD 1010 to 1220 (Leopard's Kopje A Period)

The Leopard's Kopje A sequence is found in the upper layers at Schroda and Pont Drift and has a beginning date of AD 1010. At Schroda, this period ends at approximately AD 1040, while at Pont Drift it extends until sometime between AD 1200 and 1270. *Bos taurus* and ovicaprids analysed from the main Leopard's Kopje A site of K2 come from two units that have dates of between AD 1030 and 1170 (unit TS3) and AD 1050 and 1220 (unit TS4). When combined, the K2 units span the full Leopard's Kopje A occupation.

The average δ^{15}N values for both domesticated species from Schroda (*Bos taurus*: 8.1±1.2‰, *n* = 5 and ovicaprids: 9.1±1.1‰, *n* = 12) are within <1.0‰ of the Zhizo values, suggesting an average annual rainfall between 350 mm and 450 mm. Similar values are recorded also for Pont Drift in the lower portion of the Leopard's Kopje A sequence, but are followed by values of <8.0‰. Towards the end of the sequence at Pont Drift, values of ≥10.0‰ for 8 ovicaprids and 1 *Bos taurus* hint at an episode after ~AD 1200 when annual rainfall was ≤350 mm. This climatic variability is reflected in the site average values for *Bos taurus* (7.6±2.4‰, *n* = 3) and ovicaprids (9.8±1.4‰, *n* = 12).

The two K2 units combined have average δ^{15}N values of 7.5±1.4.‰ (*n* = 16) for *Bos taurus* and 7.3±1.4‰ (*n* = 17) for ovicaprids. Overall, the individual δ^{15}N values are consistently lower at K2 compared to Schroda and Pont Drift, reflecting an increase in average annual rainfall to ≥500 mm. Based on the stratigraphic position of bone samples relative to the dated layers from these three sites, this increase in rainfall may have occurred near the start of the K2/Leopard's Kopje A sequence at ~AD 1030. From the isotopic evidence, there appears to be a general trend towards increased rainfall within the Leopard's Kopje A period.

3) AD 1190 to 1290 (Leopard's Kopje B Period)

For the Leopard's Kopje B sequence, *Bos taurus* and ovicaprids were sampled from two areas of Mapungubwe. Specimens analysed for the Southern Terrace (MST) commoner area came from Square K8, which is dated to between AD 1190 to 1260 for Layers 13 to 3, and AD 1260 to 1290 for Layer 1. On the hilltop, the elite area of MK1 is dated to between AD 1190 and 1270 for Layer 11. Thus, both areas are contemporaneous and can be compared in future research to assess similarities and difference amongst commoner and elite datasets.

From the overall MST sequence, δ^{15}N values of 7.8‰ and 7.9‰ for two *Bos taurus* are backed by the site average value of 7.9±1.2‰ (*n* = 9) for ovicaprids, with the majority of individuals having values of <8.0‰. These values are analogous to present-day average annual rainfall of ≥500 mm. This inferred rainfall level is tempered by individual ovicaprid values from layers 9, 6 and 5 that are >10.0‰, which could indicate a greater degree of climatic variability than that seen in the K2 Leopard's Kopje A sequence. Despite this variability, the δ^{15}N data from MST continues the trend of increasing rainfall, which extends through to the end of the Leopard's Kopje B sequence.

For MK1, the range of individual and average δ^{15}N values for *Bos taurus* and ovicaprids from layers 11 to 7 (6.2‰ to 13.2‰, *n* = 32) may tie into the variable rainfall conditions recorded for MST. These values support the suggestion that on the whole average annual rainfall fluctuated around 500 mm, but at times dropped below 450 mm during the early to middle portion of the Leopard's Kopje B sequence. The apparent contemporaneous overlap of drier episodes at MK1, MST and Pont Drift places this climatic episode sometime between ~AD 1200 and 1260. The δ^{15}N values from the two upper layers at MK1 corroborate the MST pattern of increased annual rainfall of ≥500 mm towards the end of the Leopard's Kopje B sequence. *Bos taurus* and ovicaprids from these two layers have a combined average value of 6.9±1.0‰ (*n* = 7).

4) AD 1310 to 1415 (Icon Facies of the Moloko Period)

Icon is a single component site dated to between AD 1310 and 1415. The average δ^{15}N value of 7.1 ± 1.5‰ (*n* = 9) for ovicaprids reflects an average rainfall level which was higher than that of present-day SLRB. With the exception of a value of 10.0‰ for one specimen, all values range between 5.0‰ and 7.8‰. Overall, these are the most ^{15}N-depleted values recorded thus far and suggest little variability within an average annual rainfall of ≥500 mm. Currently, there are no δ^{15}N bone collagen values for *Bos taurus* from Icon.

5) AD 1475 to 1685 (Moloko and Khami Period)

Faure and Kolope are single component sites dated between AD 1475 and 1685 and AD 1550 and 1655, respectively. Each site has artefacts associated with both of the archaeologically defined cultures of Khami and Moloko (G. Lathey *pers. comm.*; T. N. Huffman *pers. comm.*). The average δ^{15}N values from Faure (*Bos taurus* 8.2±0.8‰, *n* = 5 and ovicaprids 8.4 ± 1.4‰, *n* = 10) and Kolope (*Bos taurus* 9.0 ± 1.6‰, *n* = 6) mark a decrease in average annual rainfall compared to the preceding cultural sequences between AD 1030 and 1415. Based on modern herbivore values, this represents a shift from ≥500 mm of average annual rainfall to between 350 mm and 450 mm. Average δ^{15}N values for Faure and Kolope are comparable to those of the AD 880 to 1010 Zhizo sequence and the early stage of the Leopard's Kopje A sequence from AD 1010 to 1030. For Faure and Kolope, individual *Bos taurus* and ovicaprid values of >10.0‰ (*n* = 3) and <8.0‰ (*n* = 8) suggest episodes when rainfall fluctuated to below 350 mm and around 500 mm, respectively.

DISCUSSION

In the absence of clear and well-dated regional environmental sequences, the general climatic model proposed by Tyson and Lindesay (1992) provided a potential climate and environmental backdrop for agropastoral settlement of the interior of southern Africa from AD 800 onwards (Huffman 1996). However, more recent, well-dated stalagmite, pollen and tree-ring sequences for the northeastern part of South Africa are refining this climatic model, and stress the need for relatively high resolution sequences from other areas in the region. Given the high climate variability across the region, it is clear that such sequences are required also to determine how proposed climatic trends were manifested or were modified by the local environments in which early agropastoralists settled. For the SLRB, the δ^{15}N records of archaeological *Bos taurus* and

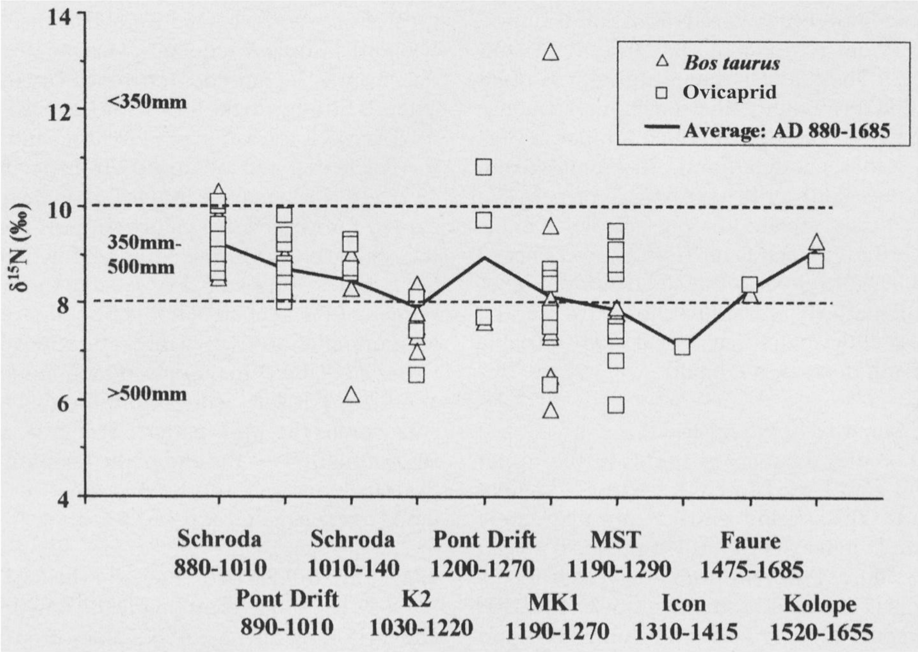

FIG. 5. *Plotted average δ^{15}N values for archaeological* Bos taurus *and* Ovis/Capra *from site layers.*

ovicaprids have established such a local sequence at a scale that can be compared to the shifting cultural occupations in this area between AD 880 and 1700.

From this analysis, we suggest a climatic sequence and an agropastoral settlement pattern for the SLRB that are not wholly congruent with existing interpretations derived from the Huffman (1996) model based on the Tyson and Lindesay (1992) general climatic reconstruction (Table 4). The isotope data suggest that between AD 880 and 1700 rainfall can be separated into three phases, two in which the average annual rainfall was similar to or marginally higher than the present-day SLRB level of ~350 mm and one when it was ≥500 mm. These wetter and drier phases are broadly consistent with the high resolution stalagmite and pollen sequences from near Polokwane, (Holmgren *et al.* 2001; Lee-Thorp *et al.* 2001; Tyson *et al.* 2002; Holmgren *et al.* 2003; Scott *et al.* 2003; Lee-Thorp 2004) and the tree-ring record from near Tzaneen (Norström *et al.* 2005).

The first of the SLRB drier phases encompassed the Zhizo cultural period between AD 880 and 1010 and persisted into the early part of Leopard's Kopje A sequence until ~AD 1030. The range of δ^{15}N values for the two Zhizo sequences sampled suggest high rainfall variability (from ≤350 mm to ≥500 mm). This degree of rainfall variability is characteristic of the present-day SLRB and is noted for southern African semi-arid regions in general (e.g. Scoones *et al.* 1996; Mortimore 1998). Our interpretation of the δ^{15}N values leads us to consider that the Zhizo chiefdom was not established because the SLRB became agropastorally viable, but because of other factors that over-rode the limits on crop and livestock production. Such factors might include the opportunity offered by an agropastorally 'empty' landscape for a new Zhizo chiefdom to establish political and economic independence, and ties to the growing southeast African coast trade network (Axelson 1973). The geography of the valley was critical in terms of its logistical relationship to the resources of trade, such as the exploitation of elephant ivory as indicated by the evidence of international trade at Schroda, and later at K2 and Mapungubwe (Hanisch 1980, 1981; Voigt 1983; Saitowitz *et al.* 1995; Wood 2000).

However, the importance of agropastoralism during Zhizo and subsequent SLRB cultural periods should not be mini-

TABLE 4. *Proposed rainfall sequences for the Shashe–Limpopo River Basin from AD 880–1700.*

δ^{15}N derived rainfall sequence	Previous climatic model	Cultural sequence
AD 1475–1685 Similar to present, 350–450 mm	AD 1650–1700 Cool and dry	Arrival of Moloko and Khami after AD 1450
	AD 1500–1650 Potentially warm and wet	
	AD 1300–1500 Cool and dry	
AD 1220–1415 Wetter than present, ≥500 mm		End of Leopard's Kopje B and Mapungubwe by AD 1290. Arrival of Moloko/Icon
Brief period within AD 1200–1260 Similar to present drier periods, ~350 mm	AD 900–1300 Warm and wet	End of Leopard's Kopje A and K2. Start of Leopard's Kopje B and Mapungubwe capital
AD 1030–1220 Wetter than present, ≥500 mm		End of Zhizo and Schroda. Start of Leopard's Kopje A and K2 capital
AD 880–1030 Similar to present, 350–450 mm		Arrival of Zhizo agropastoralists and Schroda capital

mized, and the landscape would have been critical also for sustaining crop and livestock production under less than climatically optimal conditions. For instance, as seen in current semi-arid areas of Zimbabwe (Weinrich 1975; Scoones *et al.* 1996) and northeast Botswana (Smith 2005), the SLRB contains a number of features that can offset variable rainfall levels. These include floodplains, riverbanks, wetlands formed by dolerite dykes and a range of soil types suitable for cultivation. For livestock, leaves of mopane trees, which is the dominant vegetation in the greater SLRB area, have been shown to compensate for seasonal nutritional deficiencies when grasses are diminished (Wellington 1955).

Following on the Zhizo cultural period, the δ^{15}N data support previous interpretations that the political centres of K2 and Mapungubwe arose to prominence under climatic conditions that were wetter than those of the present-day SLRB. From ~AD 1030 to 1220 there was a trend towards a higher average annual rainfall of ≥500 mm. Overall, the consistencies in δ^{15}N values suggest that rainfall variability was possibly lower in the K2 Leopard's Kopje A sequence. This wetter phase appears ~130 years later than that proposed in the general climatic model. Our data indicate that wetter conditions continued throughout the following AD 1220 to 1290 Leopard's Kopje B sequences at MST and MK1, but with higher variability in the early to middle part of the sequence at both sites. In particular, an episode of lower rainfall appears to have occurred at some point between ~AD 1200 and 1260 at MST, MK1 and in a late Leopard's Kopje A deposit at Pont Drift. Drier conditions for the Polokwane area at ~AD 1200 (Holmgren *et al.* 2001; Lee-Thorp *et al.* 2001) may indicate a more regional event. At this time average annual rainfall for the SLRB decreased to below 500 mm, and might even have dipped below 350 mm. This observation can be linked potentially to an important political and ritual shift. A centralization of ritual power, including rainmaking, and the full institutionalization of sacred leadership took place with the move from K2 to Mapungubwe (e.g. Schoeman 2006). Following this drier event the average annual rainfall increased for the Polokwane area and the SLRB recovered to the previous level of ≥500 mm, which remained at this level even *after* the abandonment of Mapungubwe at AD 1290.

The continuation of wetter conditions beyond AD 1290 therefore requires a reassessment of the causes leading to the abandonment of Mapungubwe. In light of the new isotope data, the relationship between abandonment and rapid onset of the drier conditions needs to be reconsidered. Several possibilities present themselves. One, still related to climate, is that a cropping system adapted to semi-arid conditions, such as those based on sorghum and millet, potentially could fail with *too much* rain. This is a tentative suggestion as such conditions do not preclude production of these or other crops. Studies have shown that sorghum and millet can withstand waterlogged soils and associated characteristics; for example, sorghum is tolerant also of moderately salty soils and millet grows in a wide variety of soil types (Leppan & Bosman 1923; Leppan 1928; Wellington 1960; Brady 1990; National Research Council 1996). A further climatic scenario is that higher rainfall (>500 mm per annum) could have encouraged expansion of disease belts into the SLRB, especially tsetse fly presently found to the north and east of the basin, making cattle herding in particular more tenuous (Summers 1967; Voigt 1983; Plug 2000) This pattern is evident elsewhere in Africa with increasing rainfall (Smith 1992; Gifford-Gonzalez 2000). In addition, attention needs to be given to explanations that place greater emphasis on socio-economic choices and shifts in political power within the SLRB and elsewhere in the region (e.g. Pikirayi 2001; Denbow *et al.*, in press).

The isotopic evidence for the post AD 1290 period invokes further re-consideration on how we view settlement of the SLRB first by Moloko/Icon and then by later Moloko/Khami agropastoralists. Previously, the former were seen as occupiers of the area during the dry and marginal post Mapungubwe period, in contrast to the expansion of Zhizo agropastoralists, which was attributed to wetter climatic conditions. Based on the δ^{15}N values, the appearance of small Moloko/Icon settlements in the SLRB between AD 1310 and 1415 took place when average annual rainfall was ≥500 mm. Hence, the isotope data, in conjunction with the Polokwane and Tzaneen sequences, do not support the occurrence of a dry phase in the SLRB during the 14th century AD, as postulated from the general climatic model. Rather, evidence for a regional decrease in rainfall occurs post AD 1450 and in the SLRB isotopic sequence it first appears in the Moloko/Khami cultural period sites dated AD 1475 to 1685, when average annual rainfall is estimated to have fallen to between 350 mm and 450 mm. During this second dry phase there is some variability between individual δ^{15}N values, indicating fluctuation in rainfall levels. The continued settlement of the SLRB and the greater region in the ensuing drier phase, post AD 1450, however, demonstrates that agropastoralists adequately worked around what we might perceive to be climatic limitations to crop and livestock production.

Analogues for addressing responses to and perceptions of these climatic limitations may be found in ethnographies and historical descriptions of agropastoralism in semi-arid regions of South Africa, southern Zimbabwe and Botswana (Schapera & Goodwin 1950; Schapera 1953; Summers 1967; Mönnig 1967; Scoones *et al.* 1996; Dahlberg 1996; Smith 2005). In these accounts, agropastoralists moderate fluctuation and regional 'patchiness' in rainfall through the use of low rainfall (~250 mm of annual rainfall) adapted crops such as sorghum and millets; by planting mixed cultivars with different rates of growth and moisture requirements; planting in soils with different moisture retentions; maintaining mixed livestock herds; seasonally moving livestock between vegetation types, and establishing social networks in other ecozones. As a result of differential implementation of these strategies or access to resources, drier periods or droughts are not collectively perceived in the same way by agropastoralists in a given region. Further, many agropastoralists in other semi-arid regions of southern Africa view a dry period as a temporary condition that exists either until the level of available moisture is sufficient for resuming average annual crop and livestock production, or until their economic and socio-political strategies are adjusted to compensate for the decrease in available moisture and production (Verstraete & Schwartz 1991; Ellis 1995; Swift 1996; Mortimore 1998).

CONCLUSIONS

The climatic pattern we propose for the SLRB between AD 880 to 1700 reiterates that the agropastoralist sequence must be 'read' also within a framework of cultural practices that, at the very least, emphasizes the flexibility inherent within African farming systems, and not in absolute terms where 'wetter' equates with agropastoral success and 'drier' with failure. This is underscored by three settlement periods within the SLRB, in which dry phases are interpreted as being similar to present-day conditions of the area. First is the initial settlement during a dry phase between ~AD 880 and 1030. Second is the growth in both population and agropastoral production under a wetter phase beginning at ~AD 1030. This phase led up to and continued beyond the abandonment of Mapungubwe at AD 1290, extending into a period of small-scale settlement between AD 1310 and 1415. Third is the post AD 1450 re-settlement of the SLRB during a dry phase. In this context, interpretations of environmental conditions which are seen to be more or less conducive to agropastoral success or failure need to be combined with cultural perceptions of what constitutes 'better' or 'worse' climates in a given ecology, as well as with evidence for alternative motivations and strategies for occupation. As such, consideration needs to be given to the environmental ranges and tolerances of traditional livestock and crops and of the long-standing traditional and resilient management strategies in environmentally marginal areas for agropastoral production.

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